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IDENTIFICATION OF WOOD SPECIES BY USING COMPUTED TOMOGRAPHY

Computed tomography, wood scanning, log sorting

Introduction

In woodprocessing industry the correct identification of forest species is important. Different wood species have dissimilar physico-mechanical characteristics and vary greatly in price. It makes them appropriate to special applications. Tree species are usually known at felling time but the information may be loosed during the wood chain transformation. The identity of tree can be known by examining it manually, but it takes a long time to train a person to be competent in wood identification, and also it can lead to classification errors because of the human factor. In addition, sorting by manual measurements does not correspond to current industrial speeds of logs subsequent processing. These problems motivated to develop such a system to identify the species of wood without any difficulties.

X-ray scanning is the most recent technology in woodworking. There are not any studies on wood species recognition with X-ray. The study was aimed to develop X-ray technology for identification of wood species to obtain one more benefit.

Materials and methods

The proposed work, based upon data base, derived from CT scanner, was based on five species: Norway spruce (*Picea abies*), Douglas (*Pseudotsuga*), Scots pine (*Pinus sylvestris*), Silver fir (*Abies alba*) and Larch (*Larix decidua*). Images examples are represented on the Fig. 1.

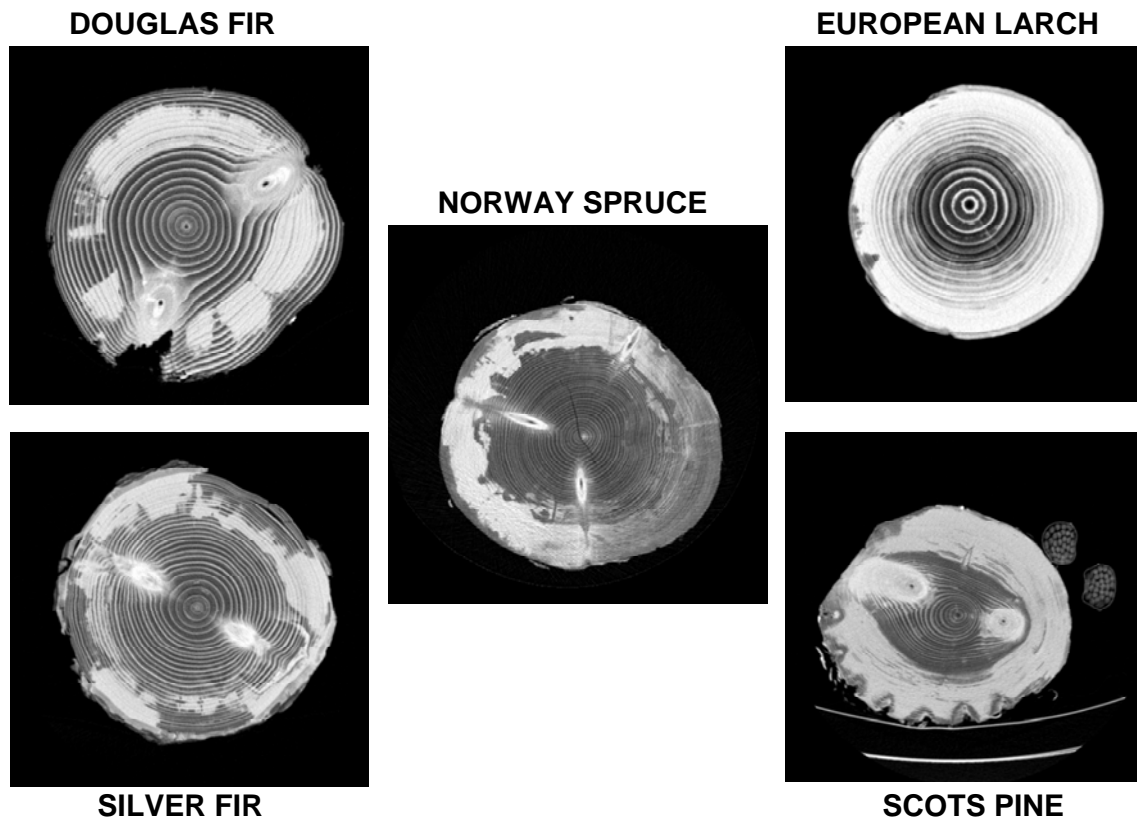


Fig. 1. Examples of CT images

The logs were scanned with a medical X-ray scanner BrightSpeed Excel by GE Healthcare. The system almost instantaneously delivers volumetric reconstruction of the sample in the form of stack of 512×512 pixels slices (the minimal pixel size was 0.2 mm for a field of view of 96 mm), with a slice thickness of 0.625-10 mm. Grey level is assigned to each pixel according to the linear attenuation coefficient of the material and can be converted easily to wood density value

For processing of the images we used the “Gourmands” plugin (Colin et al., 2007) for ImageJ (<http://rsb.info.nih.gov/ij/>). It allows user to make and record manual measurements by using different proposed tools. Different colored markers are used for coding the following elementary components. The “Gourmands” plugin allows us to measure characteristics such as knots, pith, bud traces and so on. Graphical views can be derived from a viewer (Bil3D) developed by Frédéric Mothe (1994) to present all measurements in single 3D model of the tree (Fig. 2).

Based on the manual measurements described above, a set of variables were computed (Table 1). The variables were as much as possible based on biological knowledge. For computation the chosen parameters we used parts of the logs with completed growth units (GU). The idea was to create a big number of variables which are potentially able to help for the species recognition by using such

a mathematic-statistical as box plots, PCA (Principal Components Analysis), classification tree.

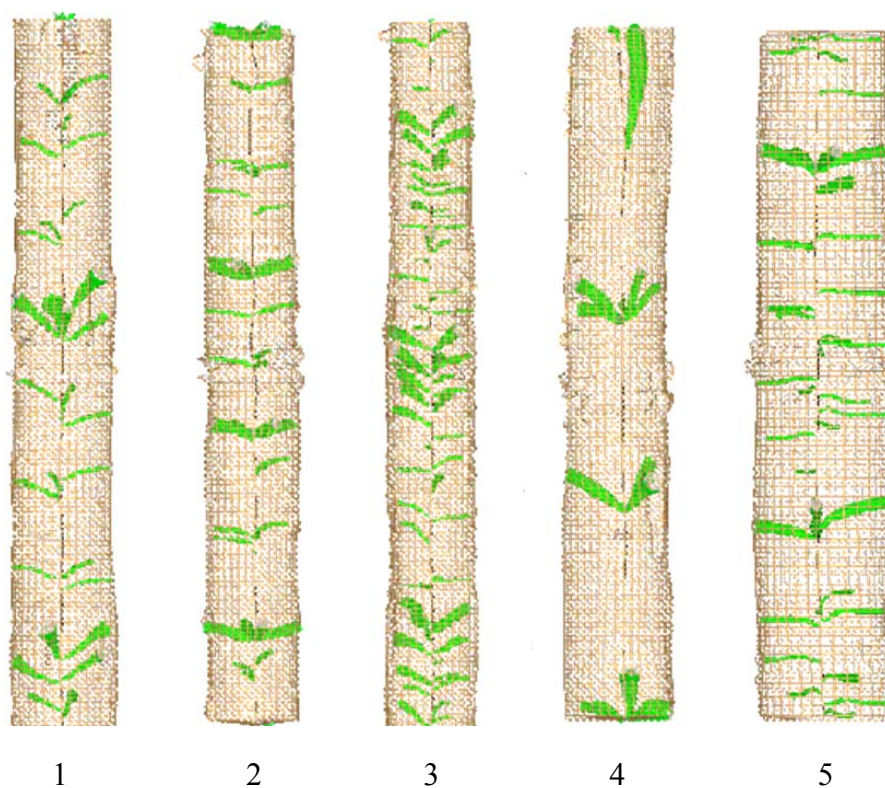


Fig. 2 Examples of 3D views for one log of each species
1 – Douglas fir, 2 – Silver fir, 3 – Larch, 4 – Scots pine, 5 – Norway spruce

Table 1

Характеристики древесных пород

Variables	Medians values according to box plots				
	Douglas fir	Silver fir	Larch	Scots pine	Norway spruce
1	2	3	4	5	6
mean of the wood grey levels	-420	-250	-380	-210	-380
median wood density in a 1 cm-diameter circle centered on the pith	-490	-190	-420	-400	-540
bark thickness divided by mean log radius	0,031	0,023	0,033	0,016	0,020
mean knot diameter for all completed GUs in each log, m	14	10	8	15	10,5
mean relative knot diameters for part of log with completed GUs	0,12	0,12	0,08	0,15	0,07
mean knot length in the log part with completed GU	0,49	0,48	0,35	0,55	0,44

1	2	3	4	5	6
mean included knot length divided by mean log radius	0,37	0,45	0,32	0,42	0,35
ratio between number of included knots and number of knots	0,13	0,13	0,68	0,66	0,4
coefficient of variation of knot diameters in part of the log with completed GUs	0,79	0,5	0,92	0,6	0,7
coefficient of variation of knot length in part of the log with completed GUs	0,2	0,12	0,35	0,24	0,2
standard deviation of relative knot diameter for all completed GU in the log	0,09	0,06	0,08	0,10	0,05
standard deviation of relative knot length for all completed GU in the log	0,1	0,06	0,13	0,11	0,09
number of knots per meter	2,5	3,5	4,8	1,1	3,2
mean number of knots per GU for all completed GUs in the log	17	9	30	3	20
mean number of knots in whorl for all completed GUs in the log	5,5	4,2	6,8	4	6
mean number of knots in whorl divided by mean number of all knots for all completed GUs in the log	0,31	0,4	0,23	1	0,3
mean value of knots inclination for all the completed GUs within log	11	10	9	33	3
mean initial knot inclination at the level of the first knot measurement	5	3	5	7	7
mean standard deviation of knot inclination for all the log of the values per slice	8	5	8	10	7
mean standard deviation of initial knot inclination for all the log of the values per slice	8	8	9	9	10
mean length of completed GUs in the log, mm	700	300	500	360	600
mean value of maximum diameters for all completed GU in log, mm	45	15	22	35	33
mean relative minimum knot diameter for all completed GUs in log	0,03	0,039	0,032	0,05	0,020
mean relative maximum knot diameter for all completed GUs in log	0,35	0,21	0,27	0,26	0,2

1	2	3	4	5	6
mean knot relative position	0,6	0,68	0,58	0,93	0,63
mean standard deviation of knot relative position from the mean value for all completed GUs in the tree	0,27	0,24	0,25	0	0,25
ratio of knot length (parameter <i>c</i>) to distance from the beginning of the knot to its end (parameter <i>d</i>)	1,015	1,02	1,022	1,05	1,015

Results and discussion

The box plots analyze revealed, that diapasons of variables variations are overlapped for different species in the most of cases. However, some variables allow us to distinguish the species from group of another ones. For example, mean gray level, that is related to wood density, (Fig. 3, position 1), for Silver fir varies from -175 to -320 units, while it greatly lower for other group species. Gray level for Norway spruce is located between -470 and -600 units, thereby the species is separable from other species. Mean number of knots per log meter (Fig. 3, position 2) and per growth unit (Fig. 3, position 3) allow us to identify Scots pine, inasmuch Scots pine logs have few knots, which are concentrated close to whorls. Relative positions of the knots are approximately equal to 1 (Fig. 3, position 5). Another species logs have a knots, which are spreaded along growth units. Mean relative knots positions of Scots pine logs are arranged between 0,88 and 0,98, for another species – they're less than 0,7. Scots pine is characterized with big knots, so it has wide variations diapason of mean relative knot diameters (0,66...0,24), and with higher value of knot sinuosity (1,041...1,052) (Fig. 3, position 6). According to the plots, mean knot inclination (Fig. 3, position 4) for Scots pine is higher than for another species (20...34). Box plots analyze show us that Scots pine could be identified easily. Douglas fir, Larch, Norway spruce have a large amount of knots with small diameter, that allow us to distinguish the group of the species from Scots pine and Silver fir. Norway spruce logs are characterized with low values of knots inclinations, which varies from -2 to 9. The Douglas fir logs were artificially pruned, that's why they have a big number of included knots. It also characterized with wide variations interval for relative included knots length.

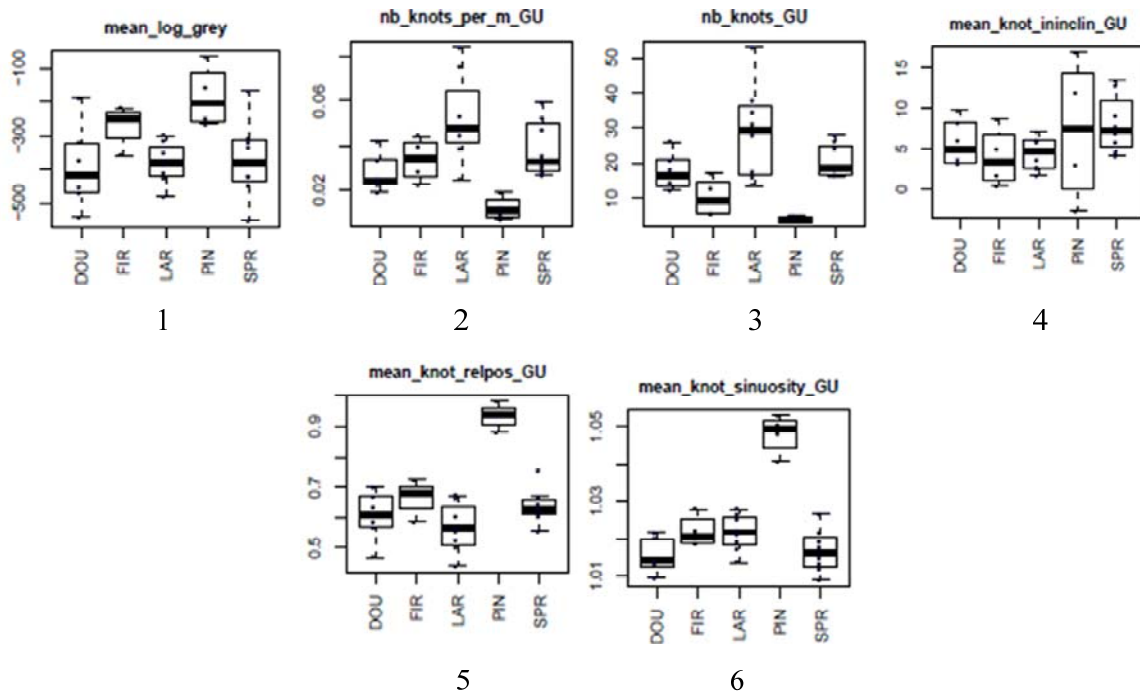


Рис. 3. Box plots examples 1 – mean of the wood grey levels, 2 – number of knots per meter, 2 – number of knots per GU for all completed GUs in the log, 4 - mean value of knots inclination for al the completed GUs within log, 5 - mean knot relative position, 6 – ratio of knot length to distance from the beginning of the knot to its end

European larch and Norway spruce differ from another species by presence a large amount of small knots, that is related to parameters “mean number of knots per meter” (0,025-0,084) and “mean number of knots per GU for all completed GUs in the log” (13-53).

PCA analyze is represented on Fig. 4, where the obtained plots allow us to distinguish Scots pine, silver fir and group of another species.

Classification tree (Fig. 5) divided all represented data into classes (species) with 100% accuracy. “Mean number of knots per GU for all completed GUs in the log”, “standard deviation of relative knot length”, “mean number of knots per meter”, “mean relative minimum knot diameter for all completed GUs in log”, “ratio between number of included knots and number of knots” are parameters, which were used for classification tree construction.

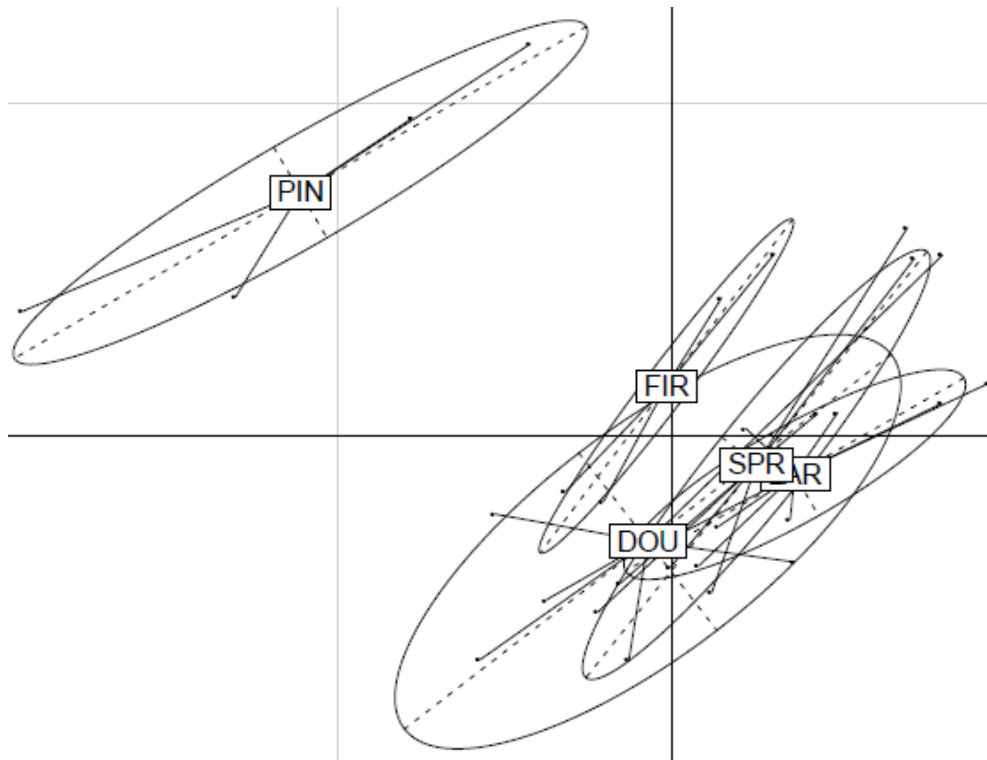


Fig. 4. PCA graph

Conclusion

Throughout the study, we aimed to develop method of wood species recognition based on the X-ray technology. Available biological material was processed and obtained data was analysed. Box plots, PCA and “Classification tree” statistical methods were applied for wood species identification.

1. Results of the analysis proved possibility of using wood species identification by computed tomography in wood processing industry.
2. Using of the three statistical methods adds one more application to computed tomography. By using big train dataset the method can be submitted for developing automatic algorithm of wood species recognition based on X-ray technology.

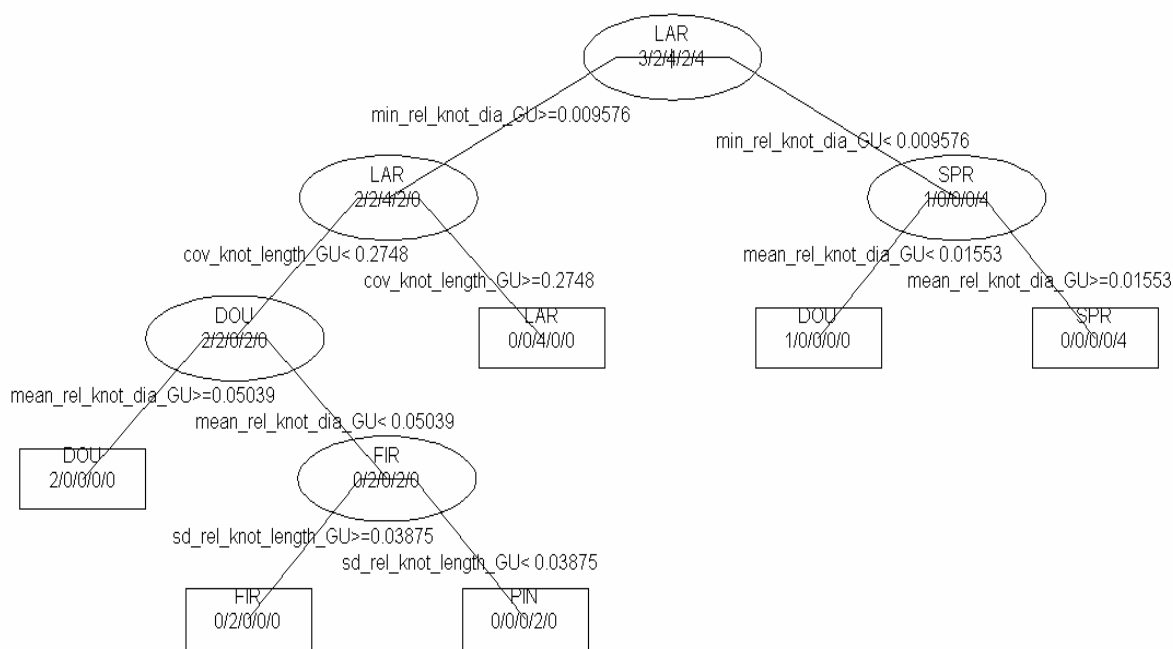


Рис. 5 Classification tree

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